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**ATLAS LAUNCHER TEST REPORT**

by R. T. Barrett  
Lewis Research Center  
Cleveland, Ohio  
November, 1969

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## SUMMARY

A series of static, cyclic and failure tests were performed on components of an Atlas rocket vehicle launcher to verify the capability of the launcher to accept the launch loads expected with the uprated Atlas SLV-3C vehicle. An A-frame from the 1967 teardown of Eastern Test Range Complex 14 and an end-frame and a launcher head from spare launchers were used for this test.

The A-frame was subjected to both static and cyclic limit "down" loads by applying the test load to auxiliary support pins. The A-frame successfully passed the cyclic and static ultimate load tests; a subsequent failure test then resulted in excessive deflection of the A-frame pin at 214% limit load.

The end-frame was subjected to both "up" and "down" static limit load and cyclic limit load tests. Load was applied to the end-frames through the support arm mechanism (head) by applying the test load to the main support pins. The end-frame withstood all test loads through ultimate load with no failures. The launcher head pin broke at 180% limit load, resulting in a broken longeron bearing. Following repair, tests were continued to 200% limit loads, at which time the dummy link (which replaced the hold-down cylinder in the test rig) broke. Inspection following these tests revealed that yielding had taken place in some areas of the end-frame. Two new launcher frame cracks and three extensions of existing cracks resulted from this end-frame test program.

TM X-52709

## INTRODUCTION

The Atlas launcher functions as a structural frame which supports the launch vehicle prior to and during liftoff. The launcher transfers its load into a concrete foundation on the launch pad (figure 1). The launchers presently used at the Eastern Test Range were designed for the Atlas 4A, with a weight of 181,000 lbs. and a thrust of 270,000 lbs. These same launchers were subsequently scheduled to be used for the uprated Atlas SLV-3C with a weight of 325,000 lbs. and a thrust of 394,000 pounds. The primary objective of the test program reported herein was to verify that these launchers were capable of sustaining the resulting increased loads with no redesign.

In addition, it was desired to increase launch availability of the vehicle by raising the allowable ground wind loads. Thus the test loads included thrust buildup, rise off disconnect loads, ground winds, rise-off moment, engine vibration loads and launch abort loads, as well as random dynamics loads. Using these criteria, limit end-frame test loads of 181 kips\* "down" and 236 kips "up" were derived. The ultimate loads were 150% of these values. In like manner, the limit and ultimate A-frame test loads were determined to be 131 kips and 196.5 kips respectively, these being in the "down" direction only.

The ultimate margins of safety, comparing the maximum anticipated uprated loads used for this test to maximum existing SLV-3C design loads, are 1.43 for the A-frame and 0.46 for the end frame as shown:

$$\text{A-frame M. S.} = \frac{196}{81} - 1 = 1.43$$

$$\text{End-frame M. S.} = \frac{271.5}{186} - 1 = 0.46$$

Stress analyses indicated that the end-frame main support pins and the A-frame auxiliary pins were the most critical components of the launcher.

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\* A kip is 1000 lbs.



The test launcher had end-frames which were removed from a spare launcher that had never been used. Spool sections were obtained from two other damaged launchers which were unfit for launches; heads were obtained from one of these three launchers; and the A-frames were salvaged from the 1967 tear-down of ETR Complex 14. All testing was done in the Lewis Research Center Space Power Chamber Facility.

In addition to the primary objective, the tests were conducted to prove that a launcher will operate satisfactorily with numerous weld cracks and other defects. Various inspections of several launchers in the field were made and most of these launchers had manufacturing defects. Due to the depth limitations of the magnetic particle inspection equipment, it was felt that many undiscovered defects were present in the launchers. New defects were sometimes detected after each launch or proof load, arousing concern that the presence of these defects could lead to catastrophic failure during a launch. The launcher used for this test program contained 114 known defects. The worst operational launcher inspected to date had 80 known defects.

### LAUNCHER TEST CONFIGURATION

The launcher provides a structural support for the vehicle in the upright position through a four-point system which is comprised of two main support pins on rotating heads and two adjustable vertical auxiliary supports (figure 1). Each rotating head is fastened at two bearing supports to an end-frame which is made up of two tripod type supports that are tied together by center cross members. A hold-down and release cylinder ties the rotating head to the center of the end-frame. This cylinder allows the head to take both up and down loads and holds the head in position until the missile builds up sufficient thrust for a launch. At this time the cylinder is vented, allowing the head to rotate and retract the pin from the longeron bearing (socket) as the missile lifts off (figures 1 and 2).

The vertical auxiliary supports previously referred to are called A-frames, due to the geometry of their construction. Each has a pin which fits into a vehicle longeron socket. These pins are interconnected by means

of a hydraulic-pneumatic system such that while the downward resistance to load of one pin increases as it is loaded, the downward resistance of the pin on the other side is decreasing. Thus the function of these two supports is to restrict vehicle tipping in the launch position by assuring equal pin deflections. The entire A-frame is pneumatically pivoted away from the vehicle as it lifts off.

### Test Equipment

The A-frames used for this test were salvaged from an operational launcher at ETR, Complex 14, when this launcher was replaced, in order to provide a test launcher in a current operational configuration. Both the end-frame and the A-frame were tested in the Space Power Chamber Facility at LeRC. The A-frame test set-up is shown in figures 3, 4, and 7; the end-frame test set-up is shown in figures 2, 5, 6, and 8. The major test components were the "Basic Tool" Launcher, the A-frames, launcher head, end-frame test beams, A-frame test beam, hydraulic cylinder and adapters and the solid link which replaced the launcher hold-down cylinder for this test. Loading was accomplished with a pneumatic-hydraulic system designed at LeRC. (All major test components are shown and identified in figures 7 and 8.)

For the end-frame test, a steel block fitted with a longeron bearing was mounted on top of a hydraulic cylinder. Once the head pin was inserted in the bearing, the head was tied to the block with eye-bolts (figure 6) to keep the pin from disengaging during loading. The test fixture was a 30 WF beam which spanned the complete launcher and transferred the load from the launcher head to the launcher support points. The load input came from a double acting 300 ton hydraulic cylinder. This method of testing was inexpensive and provided a good simulation of launch loads.

For the A-frame tests the hydraulic cylinder was fitted with an adapter which was bored to fit directly over the head of the A-frame pin. Thus, by mounting the cylinder in an inverted position on a cross beam which in turn was supported by two tension members (figures 4 and 7), it was possible to load the pin in the down direction.

The A-frame was fitted with a solid (dummy) link to replace the hydraulic-pneumatic pin support system used for an actual launch. The solid link held the pin in a fixed position so that it could be loaded and the total deformation measured during testing. (See figure 9 for close-up view of the pin area.) The A-frame retraction cylinder used for launches was disconnected during all A-frame testing so that no bending moment could be induced in the A-frame.

### Load System

Loads were applied to the test members by a hydraulic cylinder. The load applied was directly proportional to the piston area and the hydraulic pressure. An air-driven hydraulic pump was utilized to obtain the necessary hydraulic pressure. The pump discharge pressure was equal to the air pressure times a proportionality factor of 88. Therefore, the test load was directly proportional to the air pressure applied to the pump.

Two loading systems were used. Static loads were applied manually and cyclic loads were applied automatically as shown in the schematic of figure 10. The manual system consisted of controlling the air discharge pressure of pressure regulator 1 by loader 8. One psi of loader pressure equaled one psi of regulator pressure. Hydraulic fluid could be directed to the top or bottom of the ram by actuation of the 4-way solenoid valve 10. Hydraulic pressure was read out in the control room by means of transducers 13 and 14 and transmitters 19 and 22. Check valves 11 and 12 permitted unrestricted flow to the ram. The pressure could be reduced by unloading pressure regulator 1 and actuating the 4-way valve so that the pressurized line was connected to the reservoir. Valves 15 and 16 were preset for the desired hydraulic ram velocity. (Note: Depressurization and withdrawal rates were controlled by the combination of pressure regulator load value and the preset restrictions.)

The automatic cycling system utilized the same components of the manual system with the addition of an electrical timer. Since the maximum cyclic loads were known, loaders 7 and 8 could be preset to their proper

output pressures. Solenoid valve 6 determined which regulated air pressure was applied to the pump and was operated by the electrical timer. The 4-way solenoid valve 10 again diverted hydraulic flow from the pump to the top or bottom of the ram and valves 15 and 16 controlled the ram velocity.

The automatic cycling sequence was:

1. An "up" load was obtained as the 3-way air solenoid valve 6 was actuated by the electrical timer. Solenoid valve 6 connected loader 8 to pressure regulator 1. The pump discharge pressure increased to the preset loader 8 pressure.
2. Hydraulic fluid from the pump flowed through the 4-way solenoid valve 10, unrestricted, through check valve 11 into the piston head side of the cylinder. Fluid from the piston rod side of the cylinder flowed back to the reservoir, through valve 16, which controls cylinder velocity, and through 4-way valve 10.
3. The electrical timer was initially preset to assure a minimum time of 5 seconds load application. When this time had elapsed, the 4-way valve was actuated (the pump was then connected to the upper cylinder) and the 3-way solenoid valve 6 was actuated to connect loader 7 to pressure regulator 1. The hydraulic pressure built up to the preset loader 7 pressure.
4. Hydraulic fluid flowed into the upper cylinder from the pump unrestricted by check valve 12. Fluid from the lower cylinder flowed to the reservoir through throttle valve 15.
5. When the timer timed out, the 4-way solenoid valve was actuated (the pump was then connected to the piston head side of the cylinder), 3-way solenoid valve 6 connected loader 8 to pressure regulator 1, and a cycle counter was indexed one count.
6. The cycling action was repeated automatically for the required number of cycles.
7. For the A-frame, where only "down" loads were required, loader 7 was set for zero "up" load.

## Instrumentation

Instrumentation - end-frame. - All main structural members subjected to axial loads were instrumented with axial strain gages (figures 11 and 12). These gages were mounted in pairs on the Quad I side in order to measure both axial and bending loads. Since the end-frame is symmetrical, the Quad IV side had single gages as a check on the Quad I gages. Strain gages were also installed on the dummy link which replaced the hold-down cylinder on the test rig.

Those weld joints which were thought to be highly stressed, and the center 4130 steel plates were instrumented with rosette strain gages (see figures 14-18). A single deflection measurement was made between the launcher head and the floor as shown in figure 2.

Most of the strain gage measurements were recorded on Central Automatic Digital Data Encoder (CADDE) Automatic Voltage Digitizer (AVD) for a computer program which converted readings to stresses and loads. In addition, some gages were monitored on Brush recorders. Calibration of the various channels was made from the CADDE type-back and a table of calibrations was given to the computer programmer for each test run.

A TV camera was focused on the launcher hold-down pin during the static ultimate and failure tests. A rule was mounted on the launcher head to monitor deflection on TV during the test. Photos were taken of the launcher longeron bearing at the end of some cyclic tests. Photos were taken of all failed parts on failure tests (figures 19, 20, 21, 22). Photos of crack extensions and new cracks were also taken after each test (figures 23-26).

Instrumentation - A-frame. - The two pin bushing support blocks and the stabilizer bushing block were instrumented with rosette strain gages as shown in figure 27. The A-frame pin was instrumented with axial strain gages as shown in figure 28. Two additional gages were added to the pin for some of the cyclic tests, so that there were four readings  $90^{\circ}$  apart. At the same time four axial gages were installed  $90^{\circ}$  apart on the

dummy link which replaces the hydraulic stabilizer cylinder. (The dummy link gage installation is shown in figure 9.) A single deflection measurement was taken between the pin collar and the floor (figure 4). The deflection was in the "down" direction only.

Only one TV camera was used for this test set-up. It was focused on the A-frame main pin during the ultimate static test and the destruct test. Photos were taken of all failed parts and of all new cracks and crack extensions. (See figures 29, 30, and 31 for crack locations.)

## TEST PROCEDURES

### End-Frame

The initial test consisted of a static load of 181 kips "down" and 236 kips "up" as explained on page 2. (These loads compare to the present maximum design SLV-3C loads of 186 kips "down" and 181 kips "up.") CADDE and Brush readings were obtained.

After static limit testing, a series of three cyclic tests were run. These tests consisted of 25, 50, and 25 cycles, a cycle being 181 kips "down" and 236 kips "up." No CADDE data were taken during cyclic testing.

After completion of cyclic testing a static ultimate test ( $1.5 \times$  limit load) was conducted. The loads were 271 kips "down" and 354 kips "up." This test utilized CADDE and Brush instrumentation.

After the static ultimate test, two failure tests were performed. Both failure loads were in the "up" direction. On the first failure test the hold-down pin and hold-down bearing both fractured (see photos of figures 19 and 20). A reconditioned hold-down pin and a used hold-down bearing were installed for the final failure test. This test ended when the dummy link, a test piece designed to replace the hold-down cylinder, failed in tension at 448 kips (see figures 21 and 22).

## A-Frame

The initial A-frame test consisted of a static load application of 131 kips, which was derived from a bending moment of  $8.0 \times 10^6$  in-lbs. This load compares to a maximum design SLV-3C load of 81 kips.

The first cyclic test was 15 cycles at 131 kips. (A cycle is an application and release of 131 kips in the "down" direction only.)

The second cyclic test consisted of 35 cycles at 131 kips and the third cyclic test, 50 cycles at 131 kips. The fourth cyclic test consisted of 100 cycles at 131 kips and the fifth cyclic test, 200 cycles at 131 kips. The sixth and seventh cyclic tests were 300 cycles each at 131 kips. No CADDE readings were taken on any cyclic runs.

Cyclic testing was followed by a second static limit test of 131 kips as a check for yielding of the structure. This static limit test was followed by a static ultimate test of 196.5 kips. The final A-frame test was a static test to destruction.

## RESULTS AND DISCUSSION

### A-Frame

Some results and explanations of each test are described below; they are summarized in tables 1 and 2.

For the first static test, the CADDE computer calculations from strain gage measurements indicated a pin stress of 126,000 psi compression on gage 14 (see figure 28) compared to 130,000 psi compression read on the Brush recorder. The measured applied load was 130.4 kips on CADDE and 134.8 kips on Brush. Although the indicated maximum stress exceeded the theoretical minimum yield (100,000 psi) of the pin, no permanent set was detected in the pin or frame upon completion of this test. Inspection revealed no new cracks or crack extensions.

The first cyclic test initiated four new cracks (numbered 35, 36, 37, 38), as shown in figures 29 and 30. However, no permanent deformation was detected in any members, and none of the other gages except gage 13 indicated stresses above yield. The second cyclic test initiated one new crack (num-

ber 39 in figure 29) and once again no yielding was visible. The third cyclic test initiated two new cracks but there were still no visible signs of yield. (Cracks 40 and 41 in figures 30 and 31.) The fourth, fifth, sixth, and seventh cyclic tests created no new defects.

On the second static limit test, the CADDE computer calculations indicated a maximum pin stress of 171,000 psi compression on gage 14, compared to a Brush reading of 141,000 psi. (The difference in stresses between this static test and the first static test is attributed to yielding of the pin.)

For the third static (limit) test, the CADDE computer calculations indicated a maximum pin stress of 234,000 psi compression on gage 14, compared to a Brush reading of 191,000 psi. Four new cracks were initiated by this test (numbered 42, 43, 44, 45 in figure 30); however, no permanent deformation was visible.

On the fourth static (destruct) test, the pin failed in bending and compression at 272 kips (on Brush) and 251 kips on CADDE. (The Brush reading is more accurate in this case, as the CADDE reading was taken just after the peak load.) Maximum stress read on rosette gage 9-1 was 71,200 psi compression (see figure 27). Maximum stresses calculated by CADDE were 332,000 psi tension on gage 13, 373,000 psi compression on gage 14 (figure 28), and a maximum principal stress of 62,854 psi compression on rosette gage 7-1. The readings on gages 13 and 14 were erroneous, however, since these gages were not adequate to measure large strains above the elastic limit. This test initiated three new cracks, numbered 46, 47, and 48 in figures 29 and 30.

Member stresses were not measured, as structural analysis indicated that the pin, bushings and welds around the pin were more critical than structural members. No deterioration of main members was found after testing.

The only part to fail (by excessive deflection) during this test series was the auxiliary support pin. However, the top actuator bracket bolt had either yielded or the pin had bent sufficiently so that the bolt had to be burned out with a torch. The failed pin is shown in figure 34 prior to disassembly and in figures 35 and 36 after disassembly.



## End-Frame

A summary of all end-frame testing is presented in table 3. The series of tests conducted on the end-frame indicated that the weakest part of the structure is the main hold-down pin. However, the actual hold-down cylinder was not a part of the test article, so no conclusions can be drawn regarding its strength. The dummy link which broke on the second failure test was a test article which replaced the hold-down cylinder. The missile longeron bearings appear to be the next weakest link in the system. Main structural members were not yielded, and the only permanent set detected in the main launcher was the yielding around the hold-down cylinder lower attach point.

The first static test resulted in maximum calculated stresses of 33,652 psi tension on gage 1-3 and 26,867 psi tension on gage 3-8 for down loading. For up loading, the maximum calculated stresses were 39,588 psi compression on gage 1-3 and 36,885 psi compression on gage 3-8. (See figures 14 and 16 for gage locations.) No yielding of members was detected.

On the first cyclic test (25 cycles), the only significant change noted was a slightly brinelled Atlas longeron bearing. Cyclic test No. 2 (50 cycles) brinelled the Atlas bearing much more but the bearing was still not replaced until after completion of cyclic test No. 3 (25 cycles). At this time the longeron bearing was photographed both before and after disassembly (figures 32 and 33).

After completion of cyclic testing, static test No. 2 ( $1.5 \times$  limit load) was run. This test had both CADDE and Brush instrumentation. This test produced no failures, although the maximum measured stresses were well above minimum yield (33,000 psi). After the static ultimate test, two failure tests were performed.

On the first failure test (Static No. 3) the hold-down pin and hold-down bearing both fractured (see photos of figures 20 and 21). (The pin failure was thought to be the cause of the bearing failure.) The measured load was 432 kips up (on Brush) at the time of failure. The last CADDE reading taken before failure was at 379.8 kips.

A reconditioned hold-down pin and a used hold-down bearing were installed for the final failure test. This test ended when the dummy link, a

test part designed to replace the hold-down cylinder, failed in tension at 448 kips (see figures 21 and 22). The last CADDE reading before failure was at 407.4 kips.

Although no other parts failed there was evidence of launcher yield. The dummy link bottom attaching pin could not be pulled out for removal of the link. (See figure 2.) The longeron hold-down bearing was dented, but this dent was probably caused by the link failure.

An attempt was made in this test series to measure and correlate weld stresses and parent material stresses. Rosette gages were installed on welds and axial gages on longitudinal members. As noted earlier, the maximum weld stresses were 75,877 psi compression on rosette gage 1-3 (figure 14) and 54,782 psi compression on rosette gage 3-8 (figure 16), for a calculated load of 379.8 kips on the first failure test. These same gages measured stresses of 66,708 psi compression and 59,973 psi compression respectively for a calculated load of 407.4 kips on the second failure test. The smaller reading for a larger load indicates that yielding took place in the weld (weld and parent material minimum yield strength was estimated to be 33,000 psi). The highest reading on an axial gage for the 379.8 kip load was 30,000 psi on gage 5 (Brush). Thus, the axial members were not critically loaded during this test, but the welds were critically loaded.

## CONCLUSIONS

The Atlas launcher end-frame and A-frame test results indicate that these structures have adequate margins of safety (ref. p. 2) for maximum SLV-3C loads. Therefore, these launcher components can be safely used for SLV-3C launches with no major redesign. The fact that so many limit cyclic load tests were run with no adverse effects and that subsequent ultimate and failure tests were run with much higher loads than were applied during the cyclic tests shows that a single launcher can support the existing SLV-3C Centaur program with confidence. The fact that the test launcher had more cracks than any launcher previously used indicates that a large number of cracks does not necessarily make a launcher unsafe for SLV-3C launches. Each launcher must be evaluated individually.

TABLE 1. SUMMARY OF A-FRAME TESTING

(Tests were conducted in order shown)

Type of Loading	Nominal Down Load (Kips)	No. of Cycles	Deflection (in.)	Pin Stress (psi compression) Brush Readings of Gage 13	New Cracks
Static No. 1	131	1	0.18	130000	0
Cyclic No. 1	131	15	0.16	126000	4
Cyclic No. 2	131	35	0.14	124000	1
Static No. 2	131	1	0.16	141000	
Cyclic No. 3	131	50	0.12	132000	2
Cyclic No. 4	131	100	0.12	132500	0
Cyclic No. 5	131	200	0.12	132500	0
Cyclic No. 6	131	300	0.12	132500	0
Cyclic No. 7	131	300	0.12	132500	0
Static No. 3	196	1	0.30	234000	4
Static No. 4	272	1	0.48	464000	3

NOTE: The A-frame had 34 known cracks at the start of testing and 48 cracks at the end.

TABLE 2. - A-FRAME CRACK LENGTHS

Crack No.	Length (cm)	Location
35	1.8	Fig. 29
36	6.2	Fig. 30
37	1.9	Fig. 30
38	19.5	Fig. 30
39	8.2	Fig. 29
40	4.0	Fig. 31
41	14.6	Fig. 30
42	3.0	Fig. 30
43	4.9	Fig. 30
44	5.0	Fig. 30
45	15.8	Fig. 30
46	10.6	Fig. 29
47	11.6	Fig. 30
48	6.5	Fig. 30

TABLE 3. - SUMMARY OF END-FRAME TESTING

(Tests were conducted in order shown)

Type of Loading	Nominal Load (Kips)	No. of Cycles	Deflection (in.)	(See Note) Stresses		New or Extended Cracks	Remarks
				Gage 1-3	Gage 3-8		
Static No. 1	236 Up	1	0.54	-39588	-36885	0	
	181 Down		.33	+33652	+26867		
*Cyclic No. 1	236 Up	25	.52	-----	-----	0	
	181 Down		.35	-----	-----		
Cyclic No. 2	236 Up	50	.54	-----	-----	0	
	181 Down		.36	-----	-----		
Cyclic No. 3	236 Up	25	.54			0	
	181 Down		.36				
Static No. 2	354 Up	1	.81	-64770	-63974	0	
	271.5 Down		.51	+39235	+39445		
Static No. 3	432 Up	1	.89	-75877	-54782	2**	Broke hold-down pin, hold-down bearing, and rod ends
Static No. 4	472 Up	1	1.08	-66708	-59973	3***	Broke dummy link

\*For cyclic loading, a cycle is both an up and a down load.

Crack No.	Length	Location
151	17.1 cm	Fig. 22
152	17.8 cm	Fig. 22

} New Cracks

Crack No.	Length
54E	Fig. 24
99E	Fig. 25
108E	Fig. 26

} Extensions  
} of existing  
} cracks

Note: + = Tension (-) = Compression

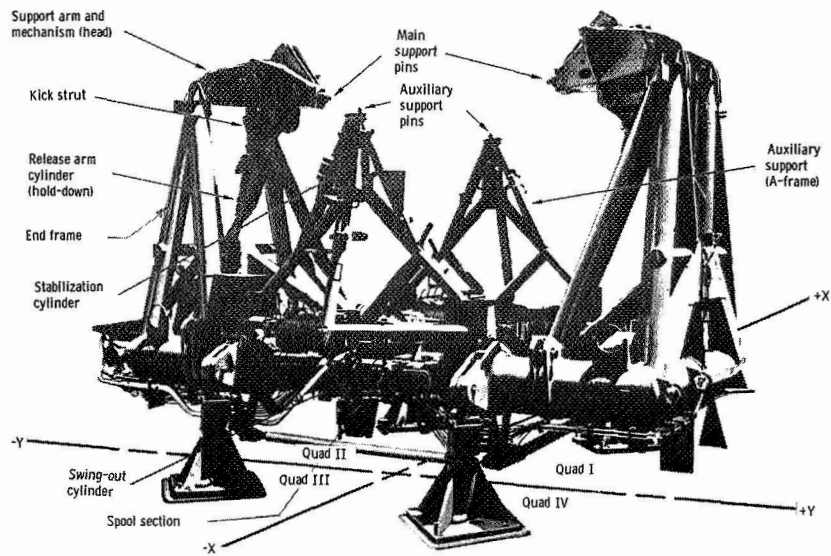


Figure 1. - Vehicle launcher configuration.

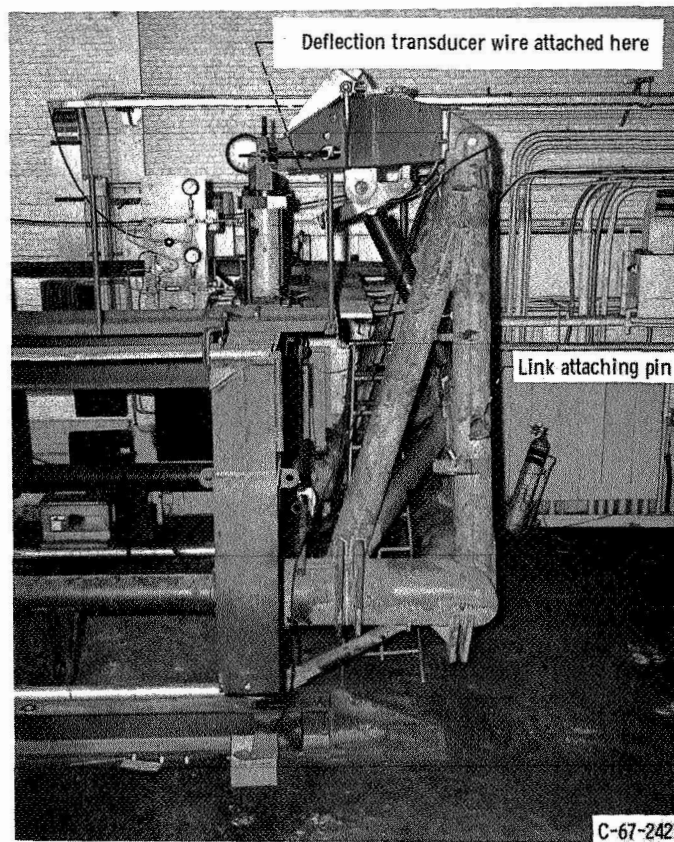


Figure 2. - End frame test set-up.

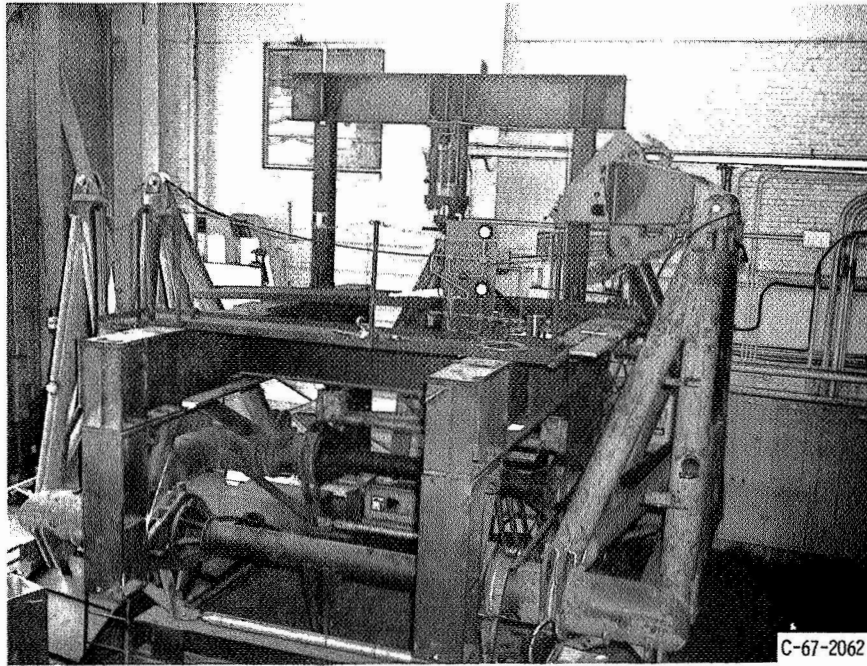


Figure 3. - A-frame test set-up.

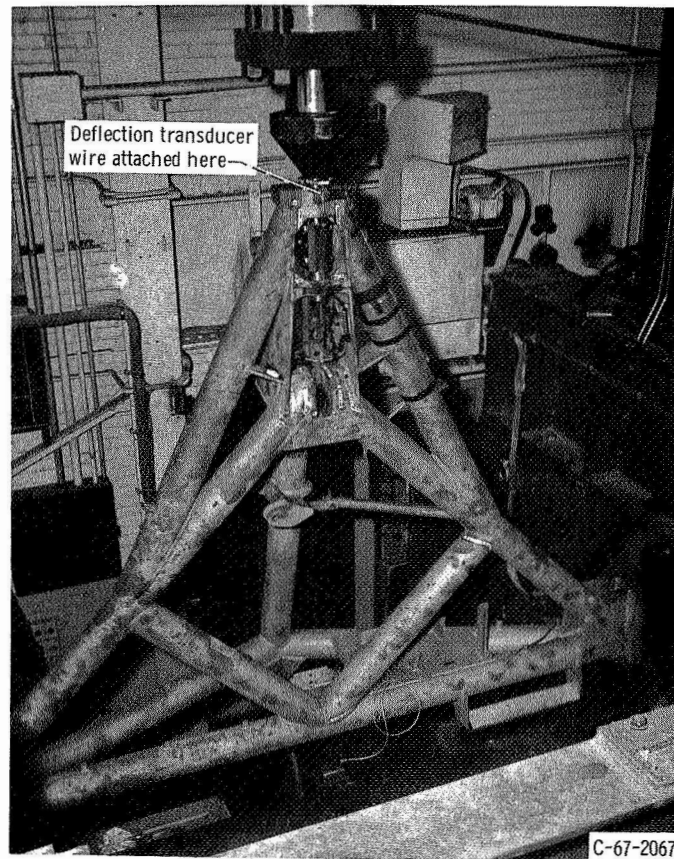


Figure 4. - A-frame test set-up.

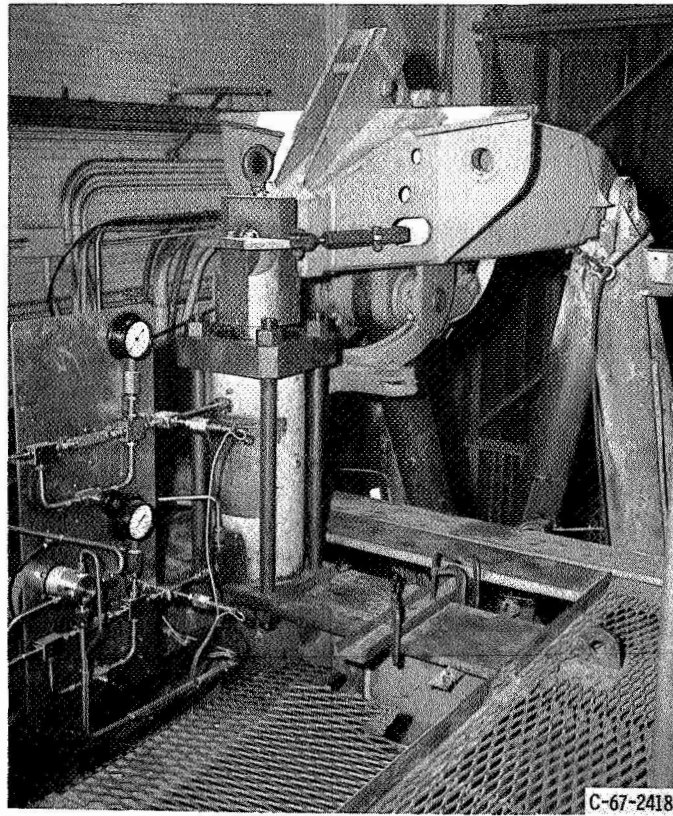


Figure 5. - End-frame test set-up.

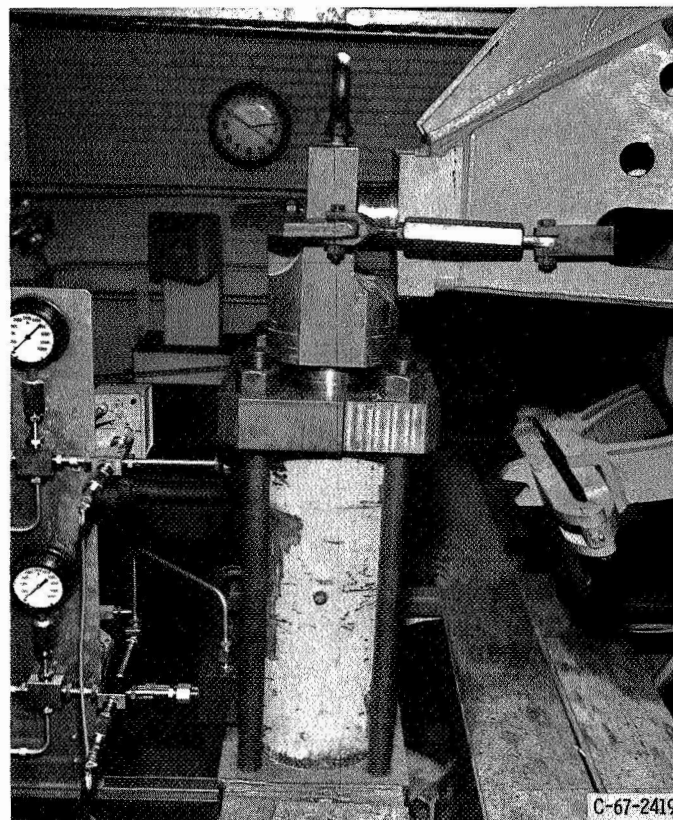


Figure 6. - End frame test set-up.



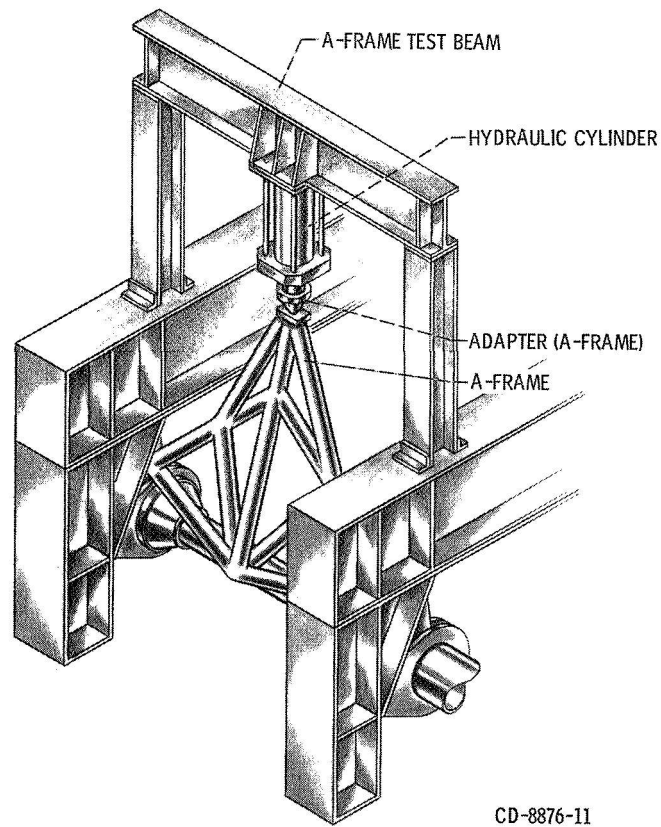


Figure 7. - A-Frame test set-up schematic.

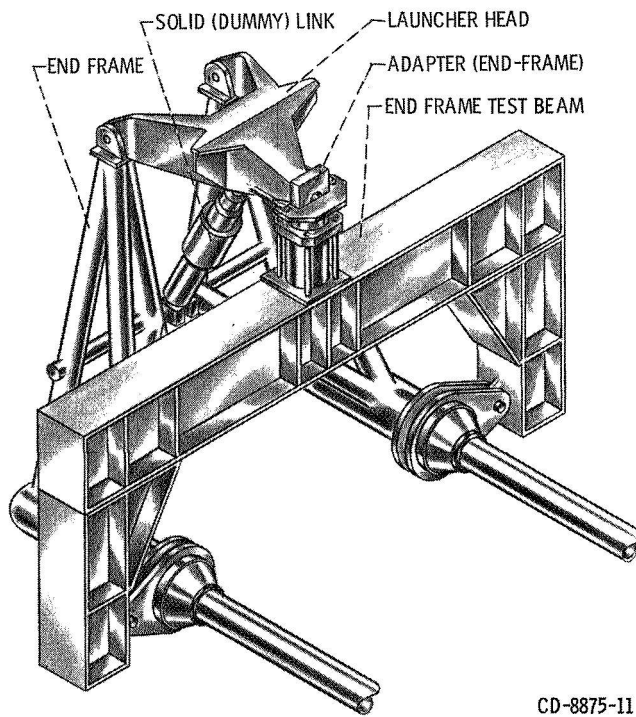


Figure 8. - End frame test set-up schematic.

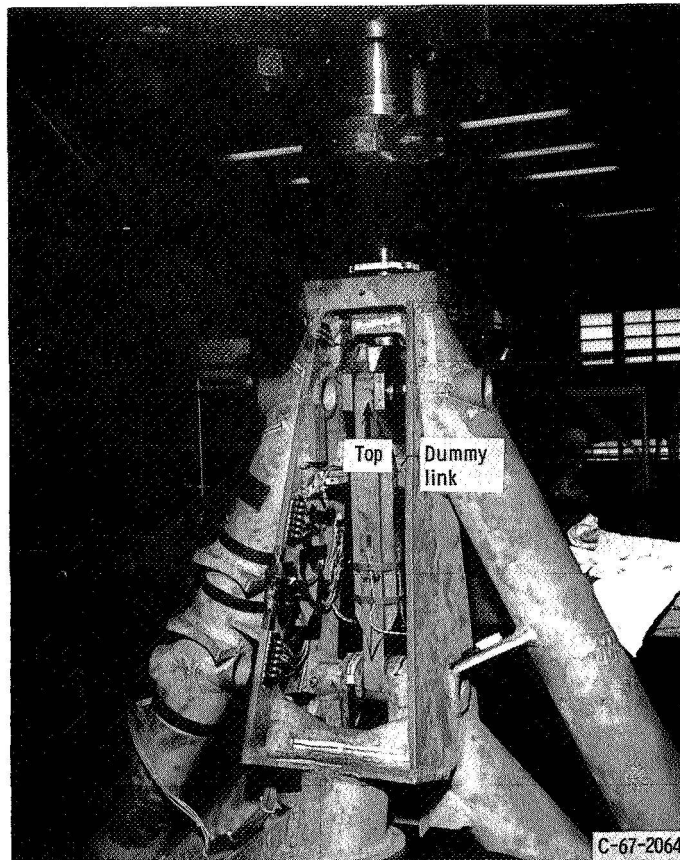


Figure 9. - A-frame test set-up.

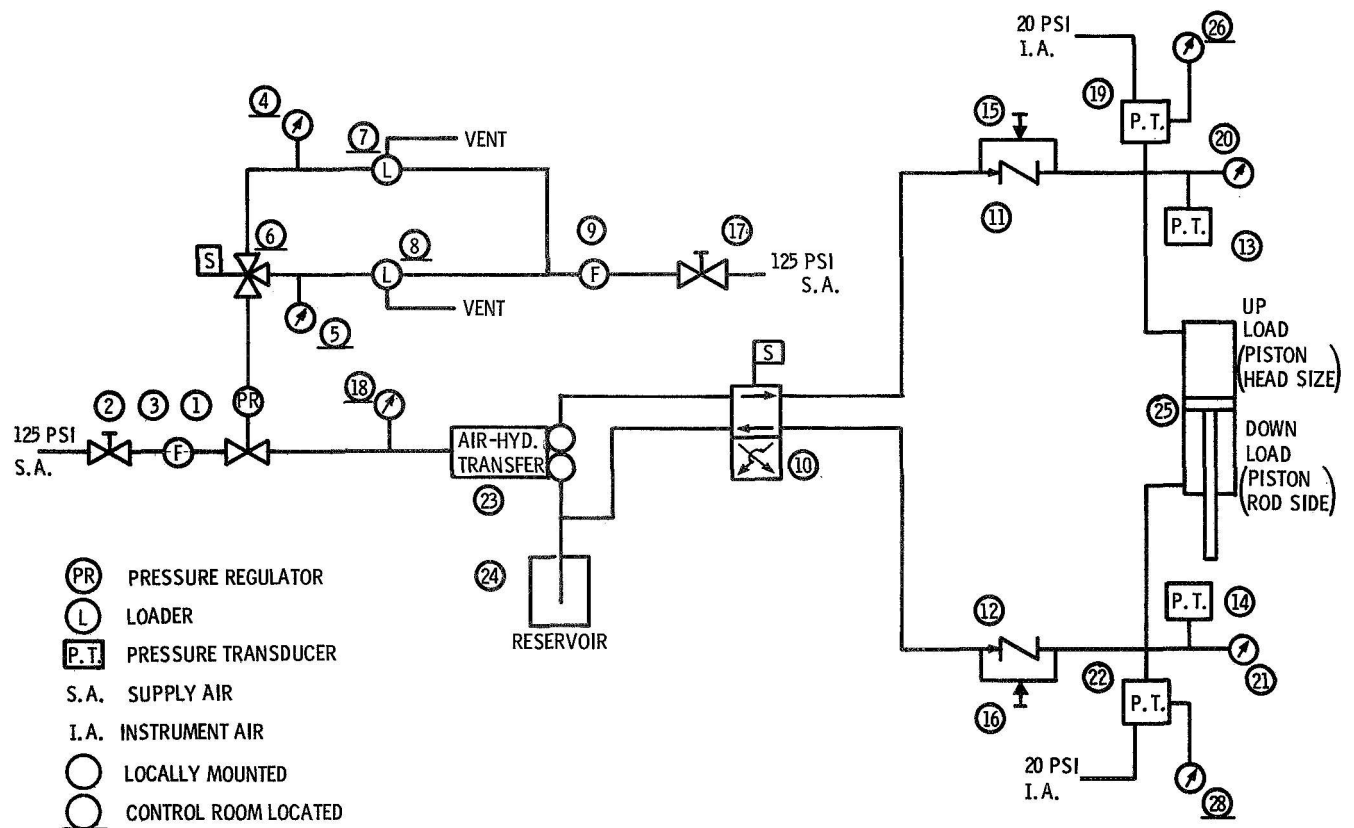


Figure 10

Note: Numbered gages were installed in pairs as shown in cases 1, 2, and 3, except that "A" gages were installed singly as a check on the paired gages.

- AXIAL LOAD GAGE
- ▲ ROSETTE GAGE

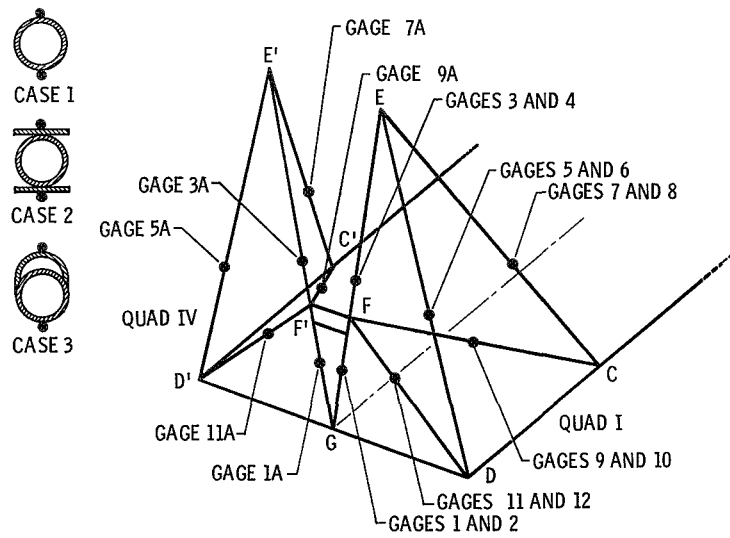


Figure 11. - End frame axial strain gage locations.

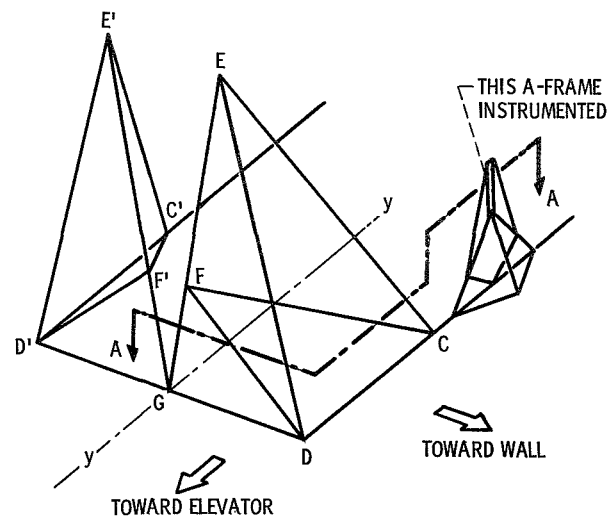
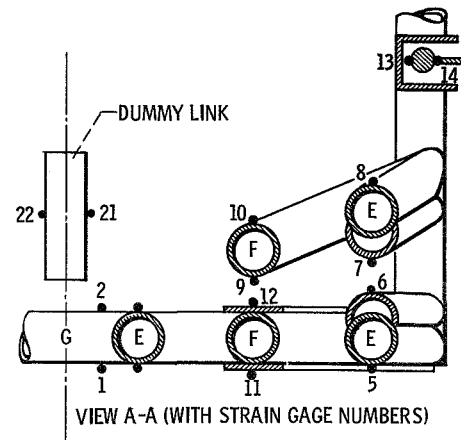


Figure 12. - Axial strain gage orientation.

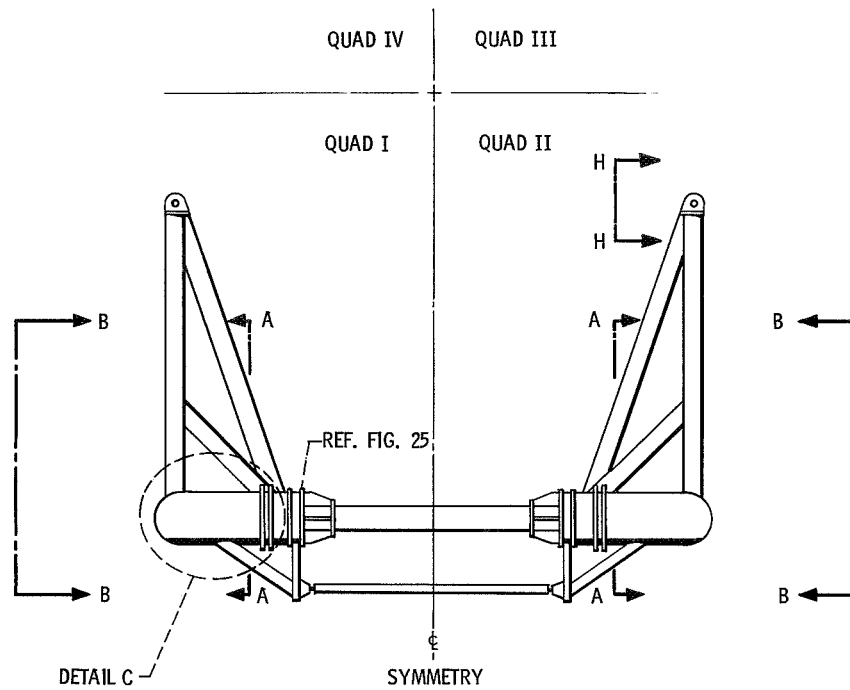


Figure 13. - Overall view of launcher.

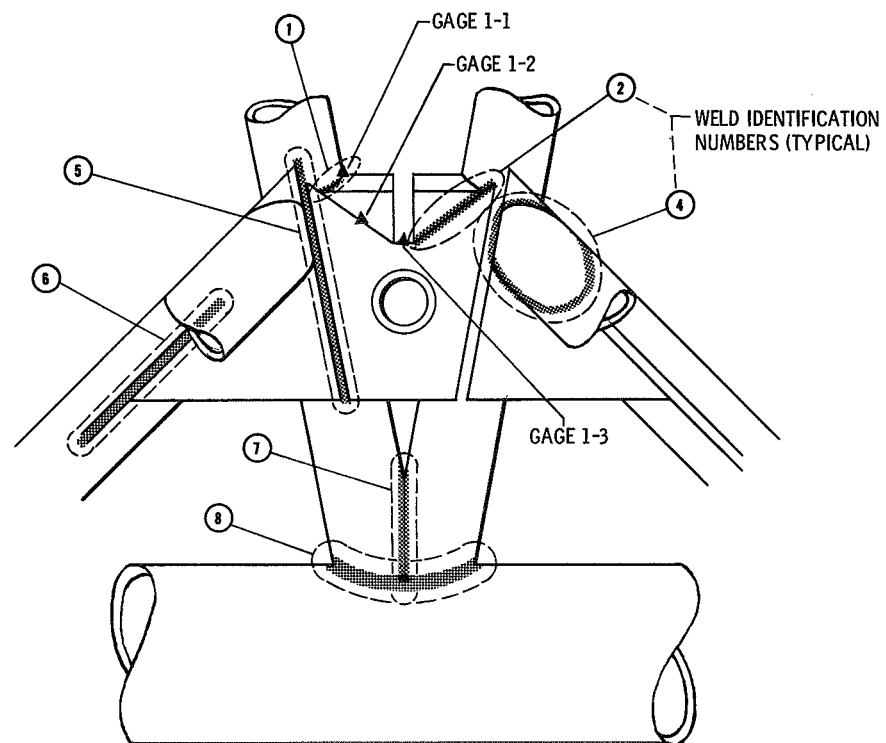


Figure 14. - View A-A (looking outboard).

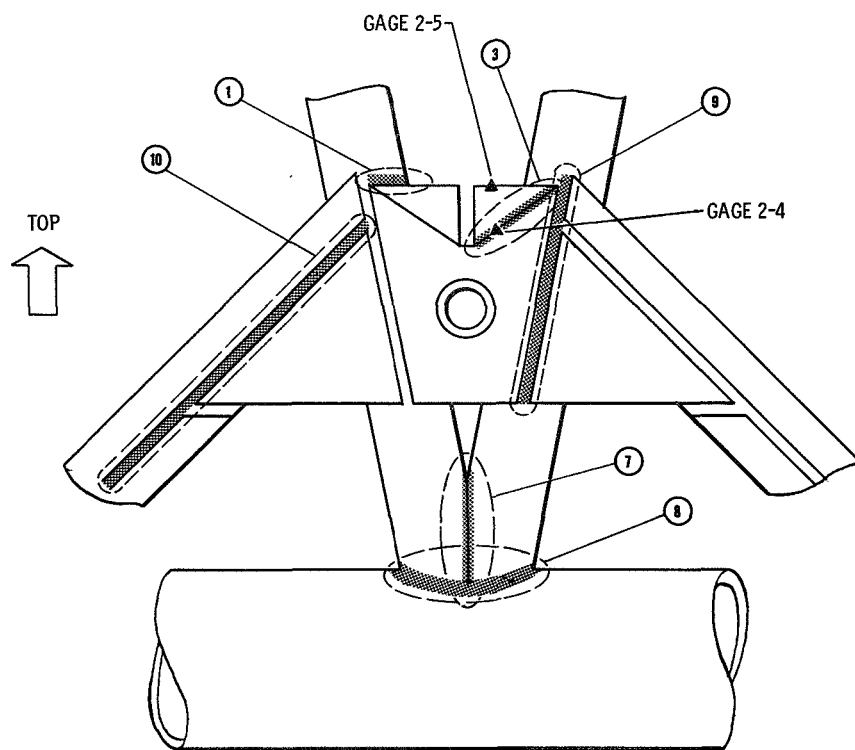


Figure 15. - View B-B (looking inboard).

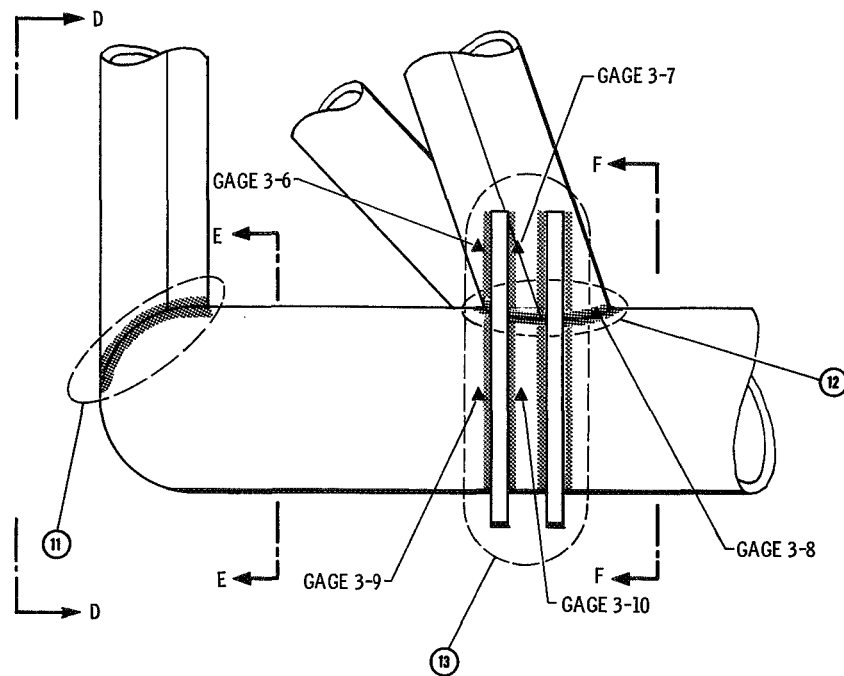


Figure 16. - Detail C (looking inboard).

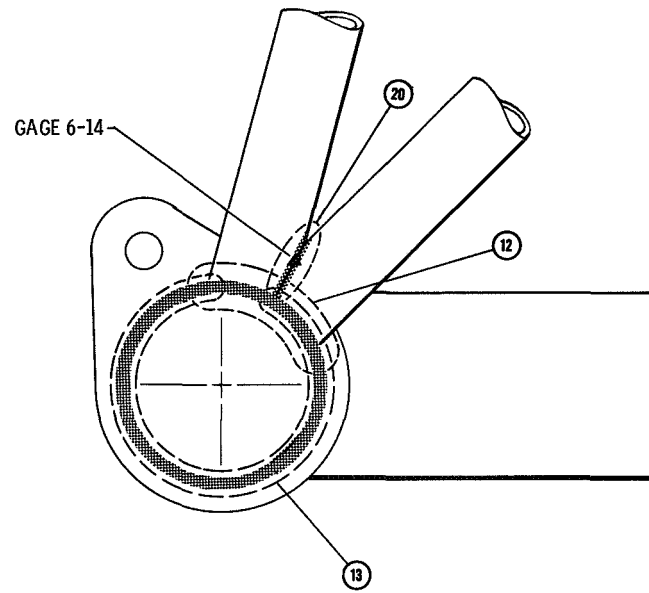


Figure 17. - View F-F (looking outboard).

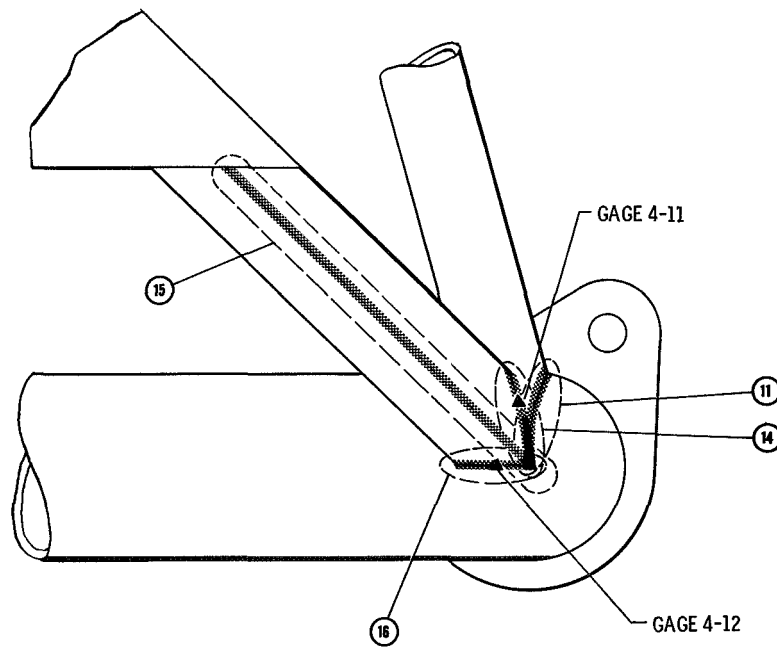


Figure 18. - View D-D (looking inboard)

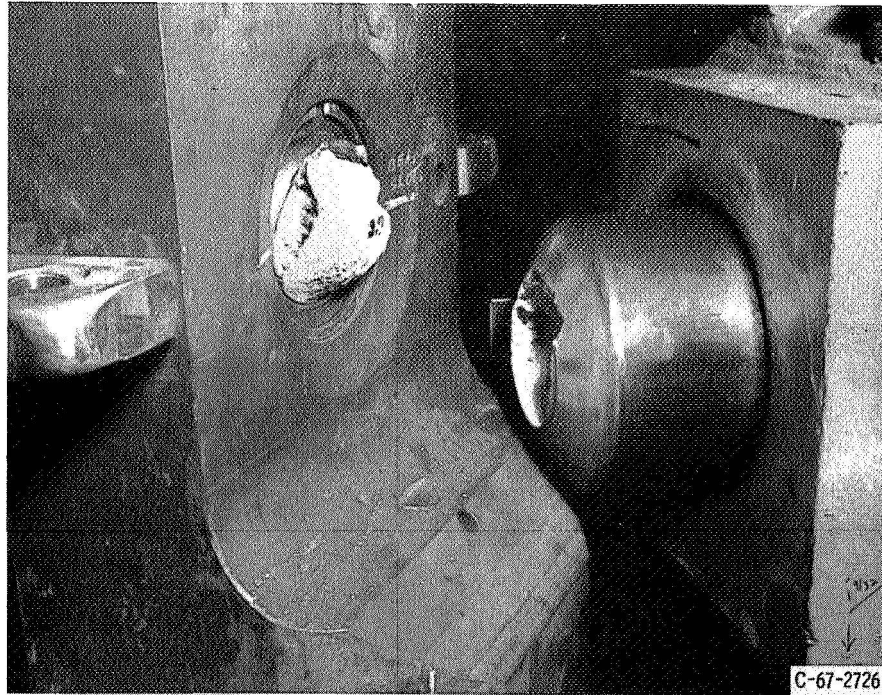


Figure 19. - First launcher failure test.

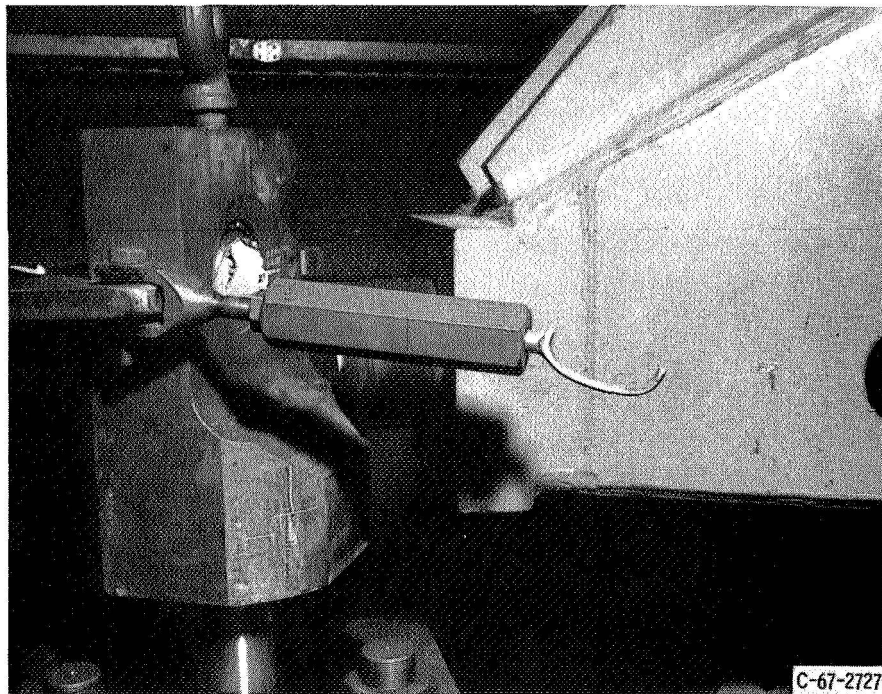


Figure 20. - First launcher failure test.

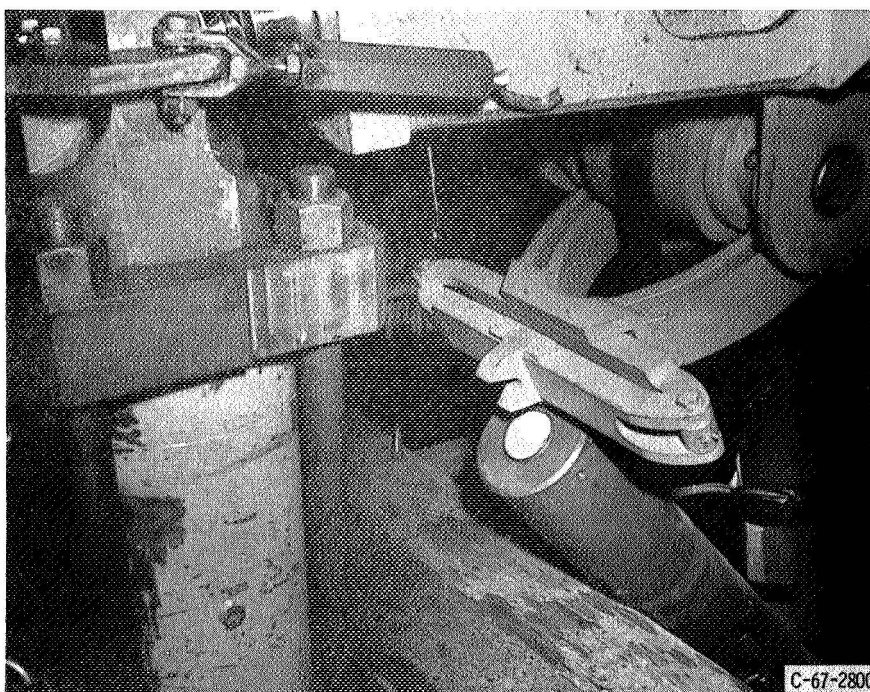


Figure 21. - Second launcher failure test.

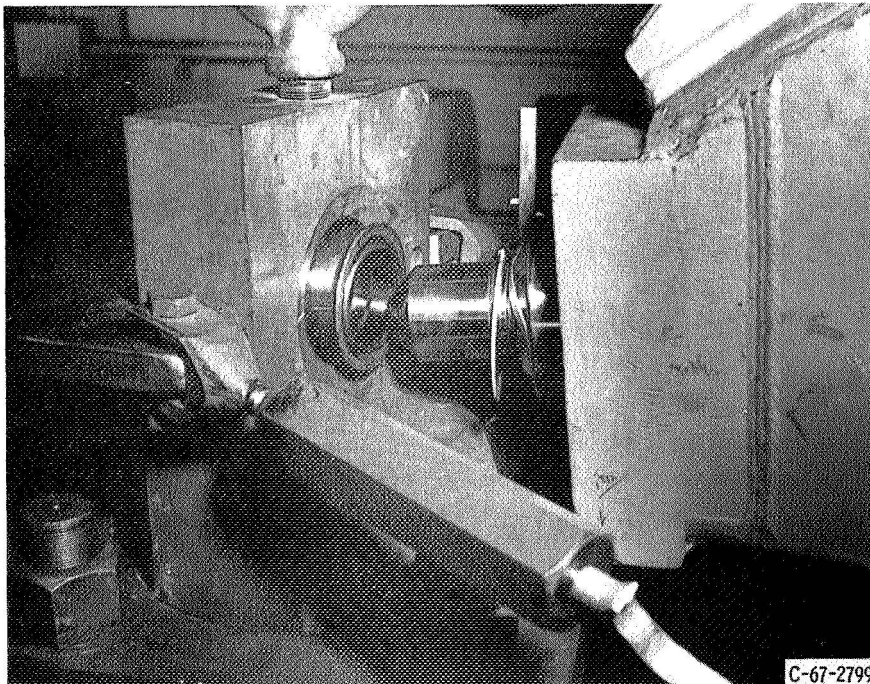


Figure 22. - Second launcher failure test.



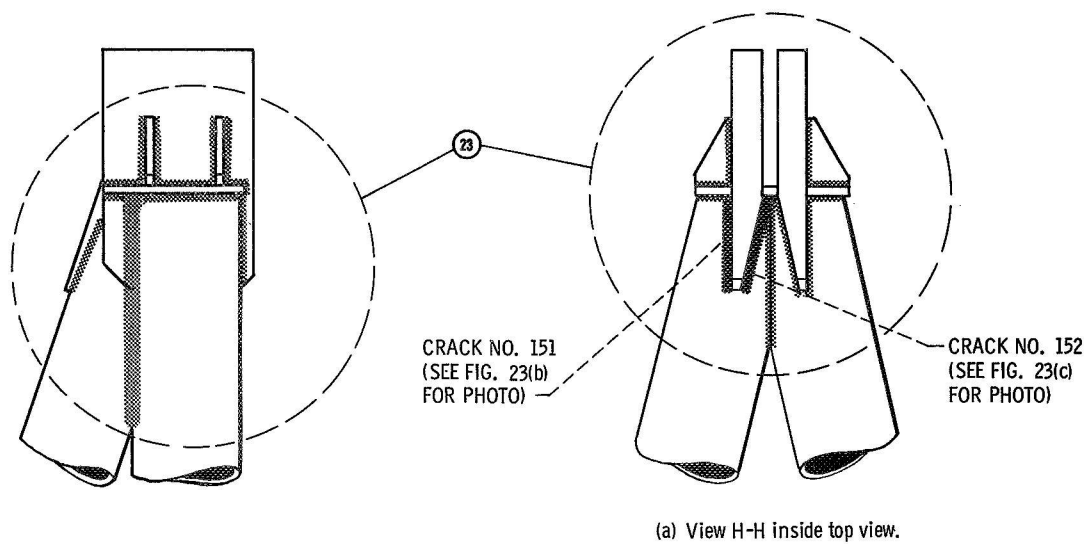


Figure 23. - End frame crack locations.

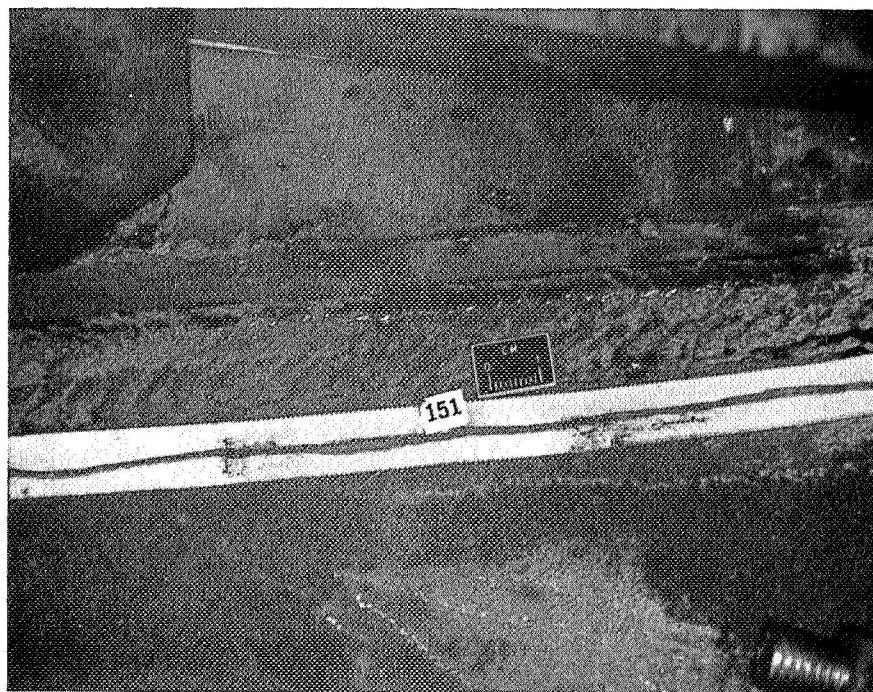
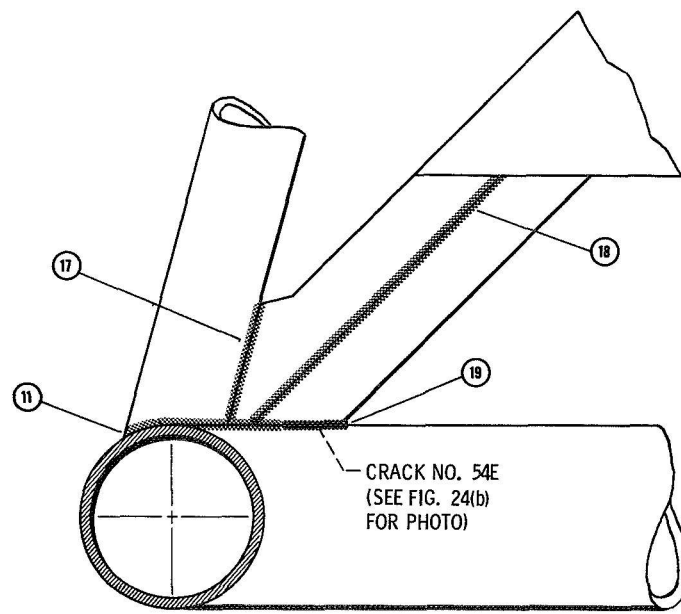


Figure 23(b). - End frame crack photo.



Figure 23(c). - End frame crack photo.



(a) View E-E (REF. FIG. 15) LOOKING OUTBOARD

Figure 24(a). - End frame crack location.

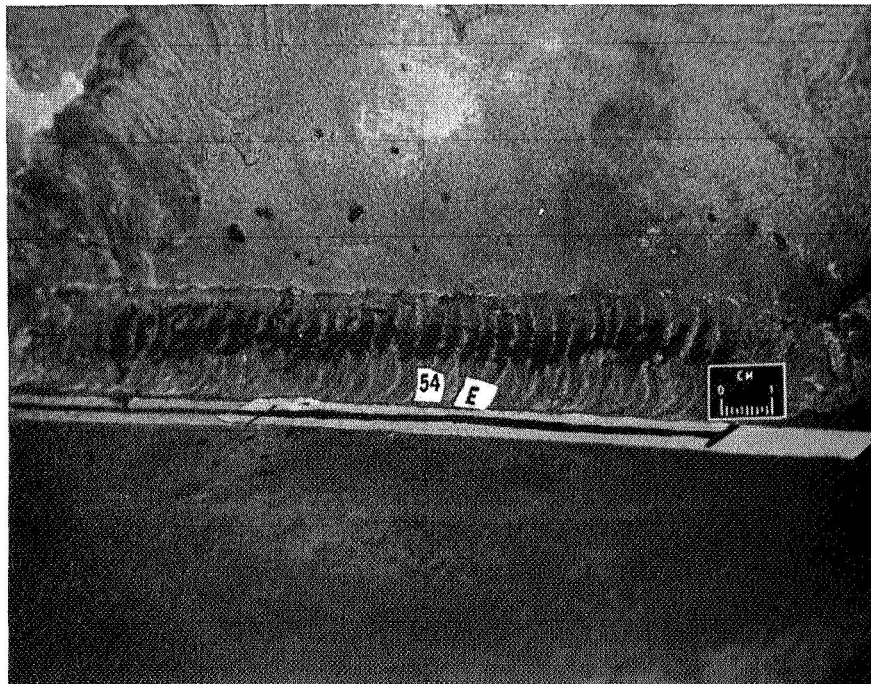


Figure 24(b). - End frame crack photo.

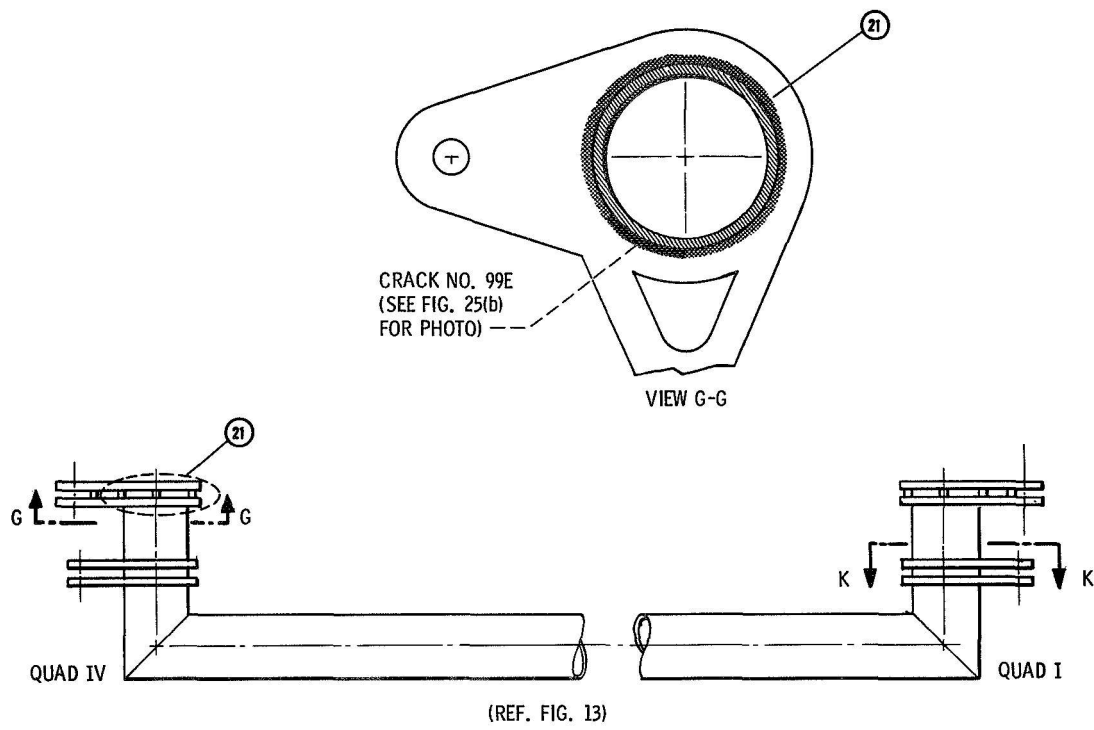


Figure 25(a). - End frame crack location.

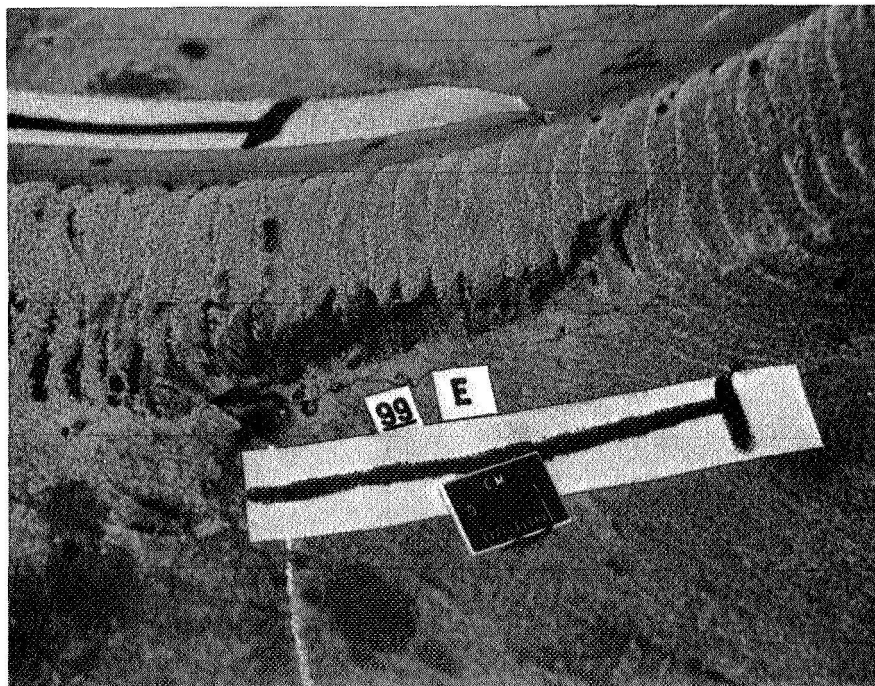
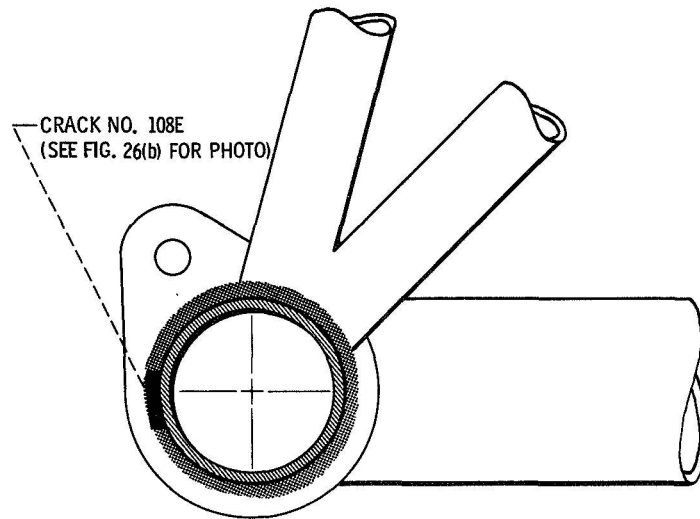


Figure 25(b). - End frame crack photo.



VIEW K-K (REF. FIG. 25) LOOKING OUTBOARD

Figure 26(a). - End Frame crack location.

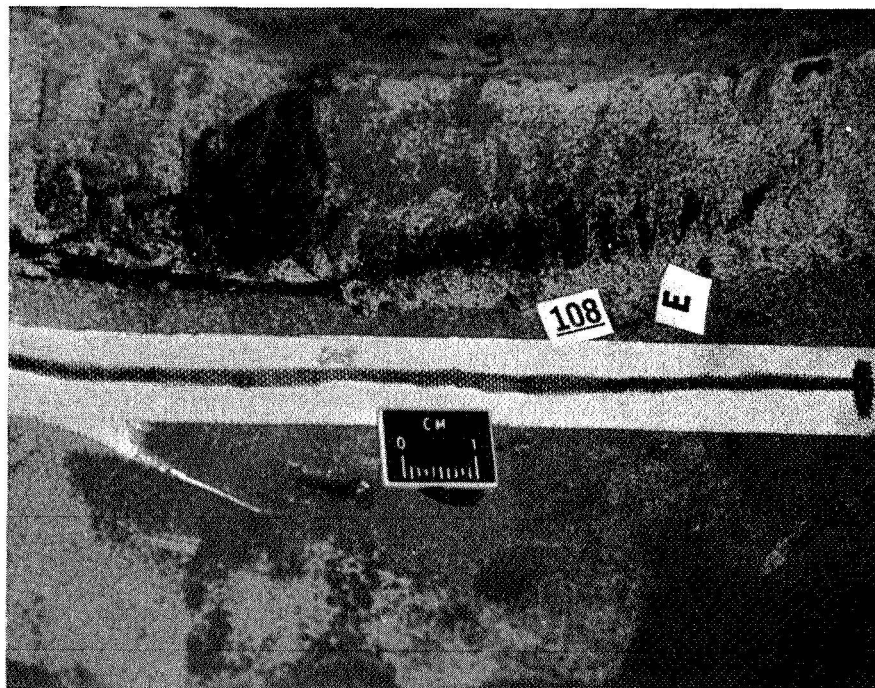


Figure 26(b). - End frame crack photo.

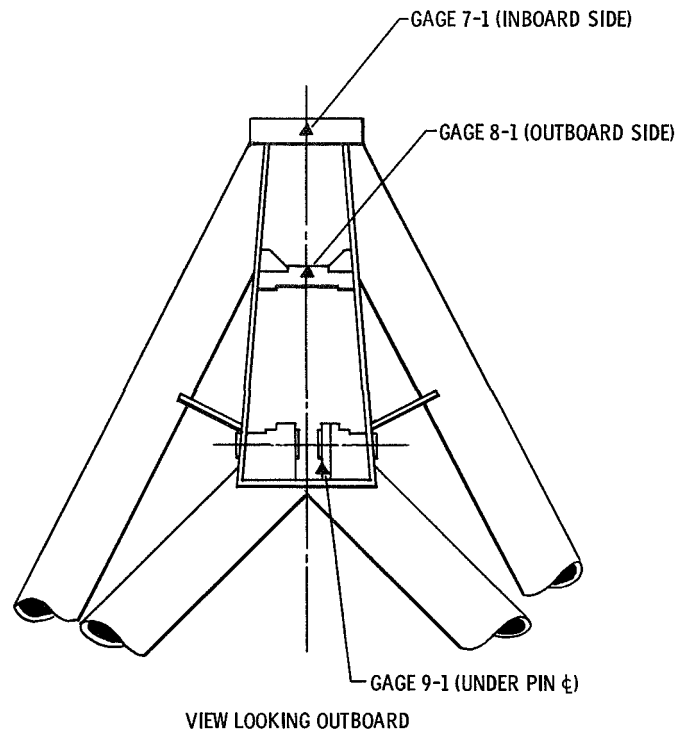


Figure 27. - Auxiliary support structure (A-frame) strain gage locations.

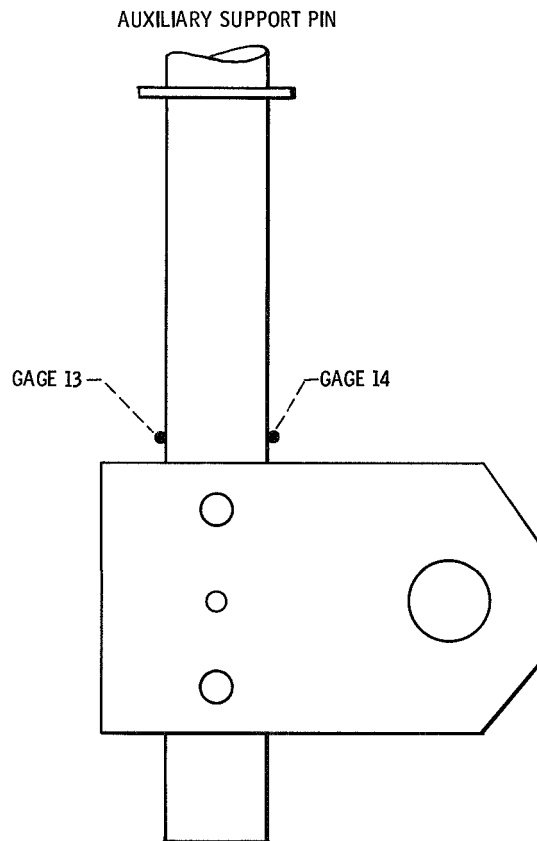


Figure 28. - Axial strain gage locations.

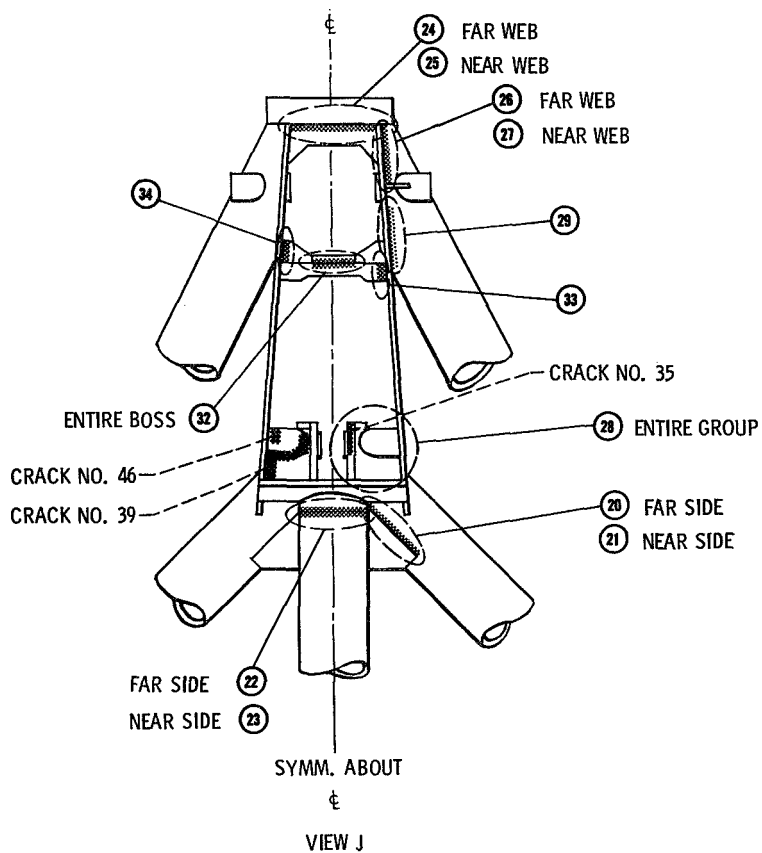


Figure 29. - A-Frame crack locations.

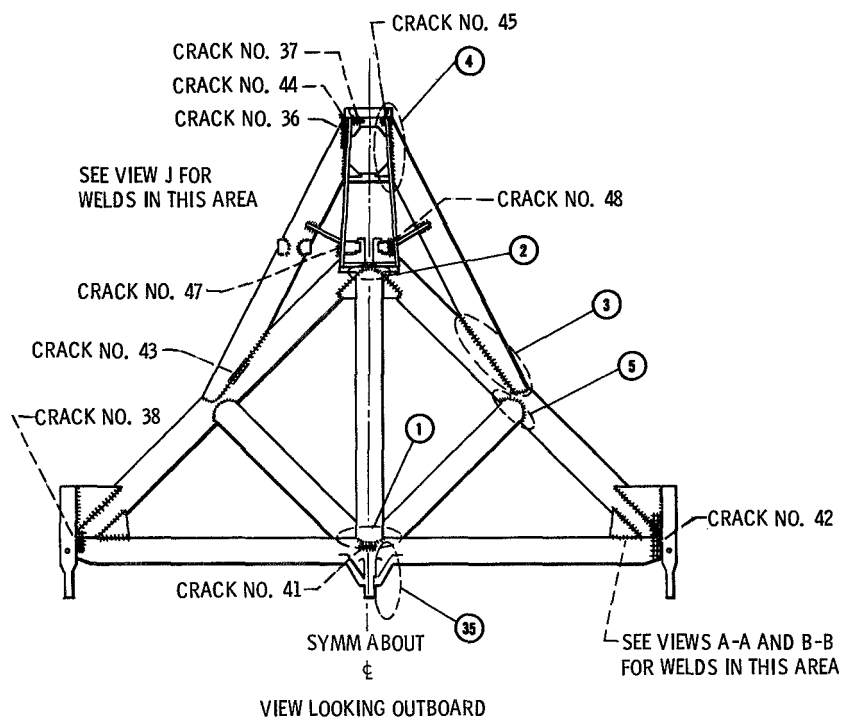


Figure 30. - A-Frame crack locations.

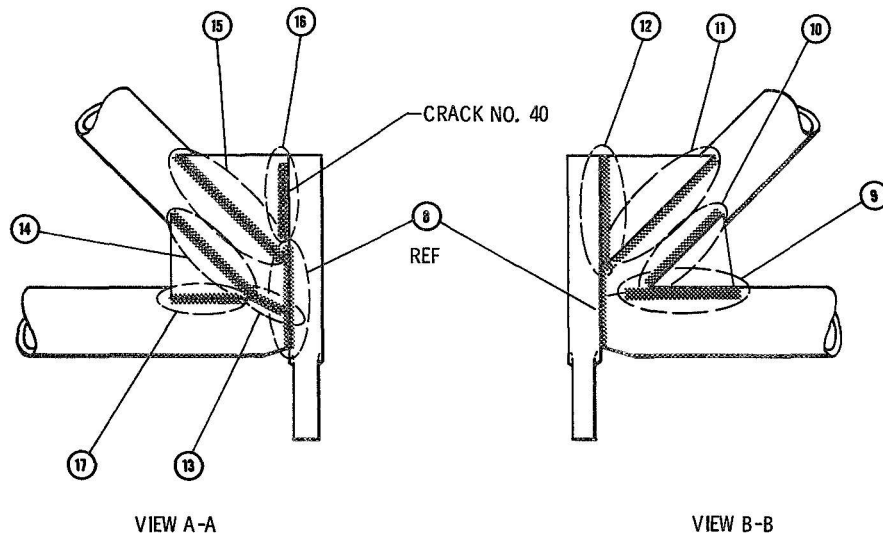


Figure 31. - A-Frame crack location.

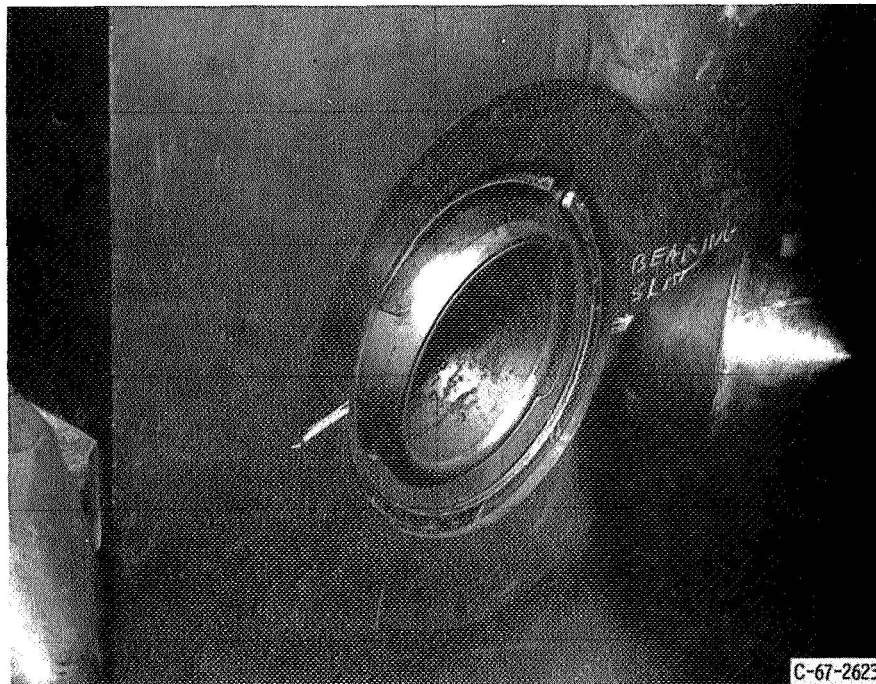
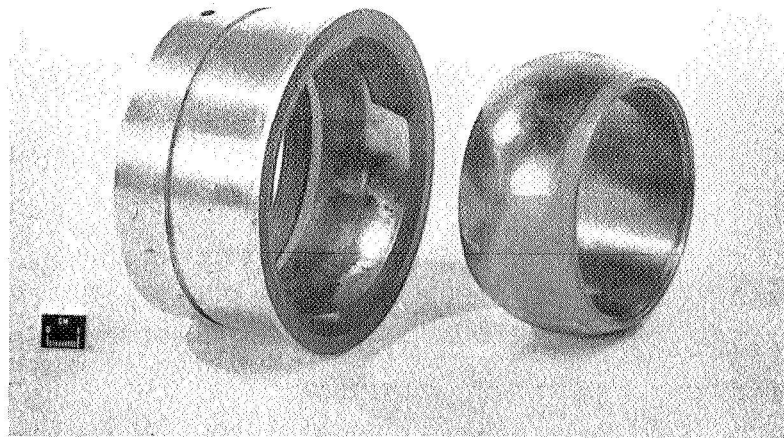


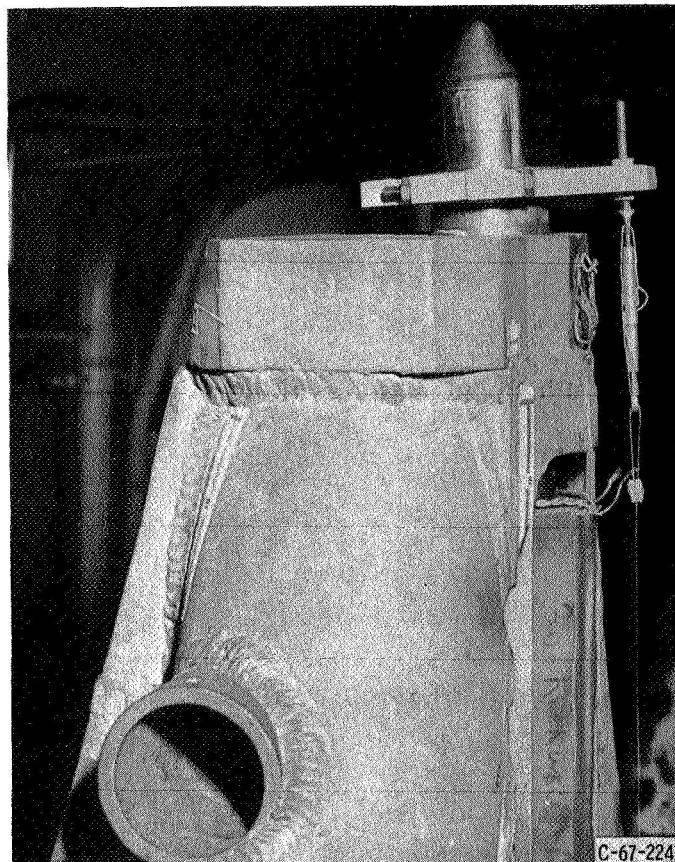
Figure 32. - Atlas longeron bearing after cyclic testing (assembled).





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Figure 33. - Atlas longeron bearing after cyclic testing.



C-67-2241

Figure 34. - Failed A-frame pin (assembled).

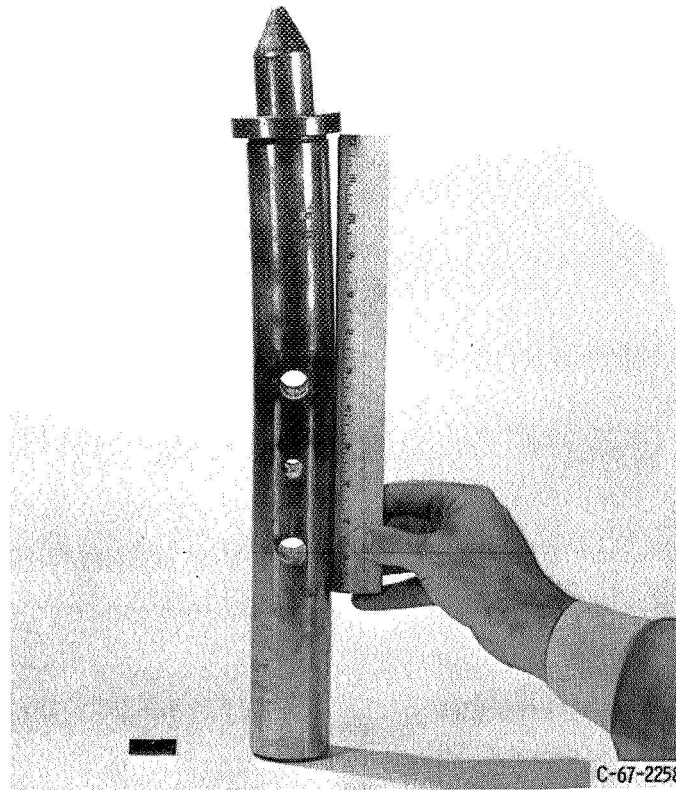


Figure 35. - Failed A-frame pin.

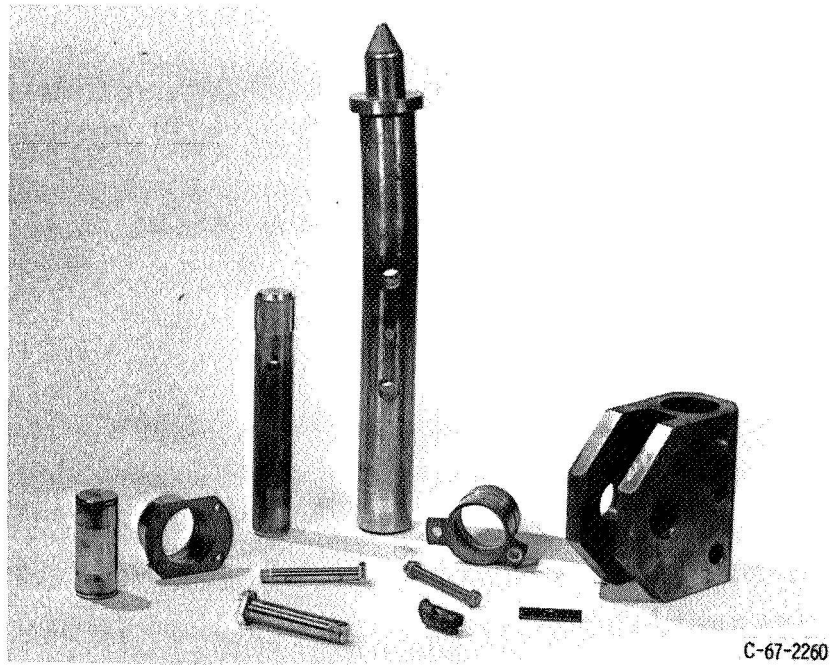


Figure 36. - Failed A-frame components.